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Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion

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CANADA-MANITOBA
AGREEMENT ON THE STUDY AND MONITORING OF MERCURY IN THE CHURCHILL RIVER DIVERSION

ANNUAL REPORT
FOR
THE PERIOD
April 1, 1984 to March 31, 1985

Canada Manitoba

Canada-Manitoba Mercury Agreement

September, 1985

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Hillsborough,
Minister of Environment,
28th Floor,
Les Terrasses de la Chaudiere,
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The Honourable Gerard Lecuyer,
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R3C 0V8

My dear Ministers:

I am pleased to present the third Annual Report of the Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion.

This report details the progress of the Agreement for the fiscal year ending March 31, 1985.

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Cochairperson,
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RÉSUMÉ POUR LA DIRECTION

Voici le troisième rapport annuel de l'accord signé le 10 mars 1983. En 1984-1985, sept projets à coûts partagés ont été mis en oeuvre. Les projets 1.2, Sources et bilan de la matière, et 3.1, Le mercure chez les animaux, ont été financés pour la première fois. Deux des trois projets sans partage de frais, ont également fait l'objet de travaux en 1984-1985. Quant au projet 1.1 sur les mesures de concentration de mercure dans l'eau et les sédiments, il a été abandonné à compter du 1er avril 1984.

On remarque tous les projets ont progressé appréciablement. Voici les résultats des travaux entrepris en 1984-1985:

1. Une étude effectuée par la Agassiz Systems, Research and Technology Ltd. visant à déterminer les sources possibles de mercure dans l'aire faisant l'objet de l'étude est maintenant terminée. Elle a permis de découvrir qu'il existait dans le centre-nord du Manitoba un certain nombre de lacs dont les brochets présentaient un niveau de concentration de mercure supérieur aux normes de commercialisation, en particulier dans les lacs où un débit accru ou une retenue soudaine des eaux, avait augmenté le niveau du lac.

Rien n'indiquait que le mercure avait été amené dans l'aire faisant l'objet de l'étude par l'homme ou par des agents naturels. On en a conclu que seuls des éléments propres à cette région pouvaient expliquer les taux élevés de concentration de mercure dans les poissons. Quant aux industries locales, comme les fonderies et les installations minières, elles semblaient n'être que pour bien peu, si ce n'est pour rien, dans la présence de mercure dans le poisson.

Il y a cependant lieu de noter que la teneur en mercure de la roche de fond est nettement plus élevée que dans la plupart des autres régions du Canada qui présentent la même lithologie. On en est donc arrivé à la conclusion, qu'à l'exception des eaux captées, la présence de mercure dans les poissons des lacs du centre-nord du Manitoba, était d'origine naturelle.

2. Les expériences relatives aux paramètres limnologiques effectuées par le ministère des Pêches et des Océans ont montré qu'un grand nombre de matières organiques, telles que les mottes de gazon et les épinettes, peuvent augmenter la concentration de methyl-mercure dans le poisson.

3. Les observations en laboratoire ont montré que la méthylation du mercure dans les terres inondées est accélérée par l'activité bactérienne qu'engendre la décomposition des plantes terrestres submergées. Une série d'expériences a également été menée afin de déterminer comment le pH, les milieux d'aérobie et d'anaérobie, la présence de mousses pulvérisées, d'algues diverses et d'argile de rivage peuvent influer sur le processus de méthylation et de déméthylation.

4. Des relevés limnologiques ont été entrepris dans le but d'étudier, à l'aide de réservoirs remplis à différents intervalles, le processus de formation du mercure dans son ensemble, et de le comparer ensuite à celui de lacs témoins. Les résultats ont prouvé qu'il existait dans tous les réservoirs un niveau de mercure suffisamment élevé pour présenter un danger et que le même processus de méthylation et de démétylation s'y produisait. Cependant le taux de méthylation et de déméthylation qui est déterminé par la croissance bactérienne, était plus élevé dans les réservoirs où les éléments organiques abondaient.

4. On a également recueilli en 1984-1985 quelque 200 visons et 50 loutres dans l'aire faisant l'objet de l'étude. L'analyse des tissus de vison terminée le 31 mars 1984 a révélé que la concentration de mercure dans ces tissus était beaucoup plus importante que chez des visons des bassins hydrographiques du sud; cependant, hormis quelques exceptions, leur teneur en mercure était loin du niveau d'intoxication.

6. Le taux de concentration de mercure dans le poisson continue d'être contrôlé dans le cadre des projets Relevés de poissons et Envois commerciaux de poissons. Les résultats obtenus cette année ne montrent aucune constance par rapport à ceux de l'an dernier. En effet, les taux de concentration relevés dans certaines espèces qui vivent dans des lacs bien précis étaient comparativement plus élevés qu'en 1984-1985, cetains avaient diminué et d'autres étaient demeurés les mêmes. Il est cependant intéressant de noter que les taux de concentration de mercure dans le brochet et le doré de la plupart des lacs étudiés sont toujours au - dessus de la limite Canadienne qui est de 0.5 ppm.

7. Santé et Bien-être Canada continue à prélever des échantillons de cheveux et à faire des analyses de sang auprès des autochtones des localités qui se situent le long du réseau de déviation de la rivière Churchill. Les résultats de son programme de 1984-1985 (du 1er juillet 1984 au 31 mars 1985) pour les localités de Cross Lake, Nelson House, Norway House, South Indian Lake, Split Lake et York Landing figurent au tableau 4.6 et ré ·lent que la majorité des autochtones testés présentaient des niveaux de mercure normaux, c'est-à-dire entre 0 et 20 ppm.

8. Un certain nombre d'initiatives ont été entreprises dans le cadre du projet de sensibilisation du public. Les 14 et 15 juin 1984 des séances d'information ont eu lieu respectivement à Nelson House et à South Indian Lake. Le thème était la présence de mercure dans le réseau de dérivation de la rivière Churchill et insistait particulièrement sur le niveau de mercure détecté chez les êtres humains. On a également produit et mis en circulation une vidéo-cassette d'une durée de 10 minutes intitulée "La présence de mercure dans le réseau de dérivation de la rivière Churchill". Citons également la mise en oeuvre dans les écoles primaires de Nelson House d'un programme sur le mercure, la mise en circulation du rapport annuel de 1983-1984, ainsi que la tenue de diverses réunions avec des particuliers ou des organisations que la présence du mercure dans l'aire qui fait l'objet de l'étude intéresse, entre autre le comité sur l'inondation des terres du Nord du Manitoba.

EXECUTIVE SUMMARY

This is the third annual report since the signing of the Agreement on March 10, 1983. Seven cost shared projects were undertaken in 1984/85, of which two were funded for the first time - Project 1.2, Source and Material Balance, and Project 3.1, Mercury in Fauna. Two of the three non-funded Agreement projects were also active in 1984/85; Project 1.1, Mercury in Water and Sediments was discontinued effective April 1, 1984.

Good progress was made on all Agreement projects. Results of the work undertaken in 1984/85 include the following:

1. A study undertaken by Agassiz Systems, Research and Technology Ltd., to investigate the potential sources of mercury in the study area was completed. One of their findings was that lakes with average mercury concentrations in northern pike in excess of commercial standards were fairly common within north-central Manitoba. In particular, water bodies which had experienced raised water levels due to impoundment or increased flows exhibited highly elevated fish mercury concentrations.

There was no evidence to indicate that significant quantities of mercury were transported into the study area, either by human or natural agencies; thus, it was concluded that the elevated concentrations observed in fish were caused by factors which were internal to the region. Local activities, such as smelting and mining operations, appeared to have little or no general impact on mercury concentrations in fish.

However, the bedrock in the region contains mercury in concentrations which are elevated with respect to most other regions in Canada of similar lithology. It was concluded that, with the exception of impounded water bodies, the mercury concentrations in fish in north-central Manitoba lakes is natural in origin.

2. Continuation of limnocorral experiments conducted by the Department of Fisheries and Oceans showed that a wide range of organic material and soils, such as spruce and sod, can enhance methyl-mercury accumulation in fish.

3. Laboratory experiments showed that accelerated methylation in flooded areas is due primarily to stimulation of heterotrophic microbial activity by decomposing remains of submerged terrestrial plants. A series of experiments were conducted to determine the effects on methylation and demethylation of such factors as pH, anaerobic and aerobic conditions, and the addition of pulverized moss, different kinds of algae, and shoreline clay.

4. Limnological surveys were undertaken with the objective of following the cycle of total mercury availability in reservoirs of different ages and comparing their cycles to control lakes, measuring different limnological parameters and the relative rates of methylation and demethylation at different locations and different times in the reservoirs. Results indicated that there was adequate mercury at every site studied to have a mercury problem and that the same processes of methylation and demethylation occurred at all sites. However, the magnitude of the methylation of the methylation/demethylation ratio was determined by bacterial growth which was higher in reservoirs because of the high organic loading in them.

5. In 1984/85 approximately 200 mink and 50 otter were collected from the Agreement area. Analysis of the mink samples that were completed by March 31, 1985 showed that the mercury levels in the tissues of the mink from the Agreement area were significantly higher than in the mink from the southern watersheds. However, with a few exceptions, the mink sampled had mercury levels well below the level at which mercury intoxication appears.

6. Mercury levels in fish continued to be monitored through the fish survey programs and the commercial fish monitoring program. Comparison of the results of the 1984/85 fish survey programs with the results of their 1983/84 programs revealed no consistent trends; mercury concentrations in some species in some lakes were higher than in 1984/85, others were lower, and some showed no change. However, the mercury levels in the northern pike and walleye in the majority of the lakes sampled continued to be above the Canadian limit of 0.5 ppm.

7. In 1984/85, Health and Welfare Canada was again involved in taking hair and blood samples for mercury analysis from the native people living in the communities along the Churchill River diversion route. Table 4.6 shows the results of their program in the communities of Cross Lake, Nelson House, Norway House, South Indian Lake, Split Lake and York Landing for July 1, 1983 to March 31, 1985. The majority of the people tested in these communities had mercury levels in the normal range of 0 - 20 p.p.b.

8. A number of activities were conducted under the public awareness program. Public meetings were held in the communities of Nelson House and South Indian Lake on June 14, 1984 and June 15, 1984 respectively. The purpose of these meetings was to discuss mercury in the environment of the Churchill River Diversion, with special emphasis on mercury levels in the people. A 10 minute videotape entitled "Mercury in the Churchill River Diversion" was produced and released. Other activities included the introduction of a school program on mercury for elementary school students in Nelson House, wide distribution of the 1983/84 Annual Report, and discussions with individuals and organizations interested in mercury in the Agreement area, such as the Northern Flood Committee.

TABLE OF CONTENTS

Executive Summary

Chapters

		Page
1.	Introduction	
	1.1 Year in Review	1
	1.2 Administrative Arrangements	2
	1.3 Financial Arrangements	2
2.	Program 1	
	2.1 Project 1.1, Mercury in Water and Sediments	4
	2.2 Project 1.2, Source and Material Balance	4
	2.3 Project 1.3, Mobilization and Methylation	7
3.	Program 2	
	3.1 Project 2.1, Experimental Ecosystems	8
	3.2 Project 2.2, Bioaccumulation Processes	10
	3.3 Project 2.3, Biogeochemistry of Sediments	10
	3.4 Project 2.4, Limnological Survey	12
4.	Program 3	
	4.1 Project 3.1, Mercury in Fauna	19
	4.2 Project 3.2, Commercial Fish Surveys	22
	4.3 Project 3.2, Fish Surveys and Fish Eating Guide	29
	4.4 Project 3.4, Mercury in Hair of Native People	31
5.	Program 4	
	5.1 Project 4.1 Public Awareness	33

LIST OF TABLES

		Page
Table 1.1	1984/85 Budget and Expenditures, by Project.....	3
Table 3.1	1984 Mercury Concentrations from DFO's Fish Survey Program.....	18
Table 4.1	Total Mercury in 1984 Mink Samples.....	20
Table 4.2	Total Mercury in 1983 Mink Samples.....	21
Table 4.3	Mercury Results for 1984 Calendar Year for Selected Lakes, Commercial Fish Monitoring Program.....	26
Table 4.4	Northern Flood Agreement Area Lakes.....	28
Table 4.5	Mean Mercury, Length, and Weight of Various Fish Species Sampled from Lakes Along the Churchill River Diversion Route and Nelson River, 1984.....	30
Table 4.6	Results of the Mercury Monitoring Program in Six Northern Communities from July 1, 1983 - March 31, 1985.....	32

LIST OF FIGURES

		Page
Figure 3.1	1984, ^{203}Hg Uptake by Perch Muscle.....	9
Figure 3.2	Relationship Between Reservoir Age and Peak Methylation to Demethylation Ratio (M/D) of Flooded Terrestrial Material and Comparison with M/D of Littorial Sediments in Control Lakes.....	15
Figure 3.3	Total Mercury in Netplankton 1984 Reservoir Study.....	16
Figure 4.1	Total Mercury in Mink Brain, Burntwood, 1984.....	23
Figure 4.2	Total Mercury in Mink Brain, South Indian Lake, 1984.....	24
Figure 4.3	Total Mercury in Mink Brain, Split Lake, 1984.....	25

GLOSSARY

APPENDICES

A.	1984/85 Agreement Participants.....	41
B.	"Work-in-Progress" Meeting Participants.....	49
C.	Script of Videotape "Mercury in the Churchill River Diversion"....	51
D.	Location Maps.....	56

CHAPTER 1. INTRODUCTION

1.1 Year in Review

All seven of the cost shared projects scheduled to be underway in 1984/85 were undertaken, namely Projects 1.2, 2.3, 2.4, 3.1, 3.3, 4.1, and 4.2. Analysis of results and preparation of reports continued on two projects for which Agreement funding is completed - Projects 1.3 and 2.2. Additional field work was completed under Project 2.1 with funds provided by the Department of Fisheries and Oceans. Two of the three non funded Agreement projects were active in 1984/85 - Projects 3.2 and 3.4. Project 1.1, the other non funded Agreement project, was discontinued in April, 1984. Project 4.3, the remaining project of the fourteen Agreement projects will be funded only in 1985/86.

The second annual "Work-in-Progress" meeting, held on January 17, 1985, was very successful. As with its predecessor, the purpose of this meeting was to provide a forum whereby the project leaders could present their findings to date and where all Agreement participants would be given the opportunity to discuss these findings. In addition to the Agreement participants, other invited guests included: representatives from Agassiz Systems, Research and Technology Ltd., who made a presentation on the report they had prepared under Project 1.2; individuals from the Manitoba region of the Department of Health and Welfare who are especially concerned with the relationship of mercury and health in the residents of Nelson House and South Indian Lake; and Dr. T. Kershaw from the Thunder Bay Office of the Department of Health and Welfare, who was the luncheon guest speaker. The topic of his presentation was "The Toxicology of Mercury in Humans". A complete list of this meeting's attendees will be found in Appendix B.

At the February, 1985 meeting of the Steering Committee, Mr. D. Kimmett, formally advised the other members of the committee of his pending departure to assume new responsibilities in Ottawa. It was noted that his active involvement in all aspects of the Agreement and the guidance which he has provided in fulfilling the Agreement objectives will be greatly missed. The new representative on the Steering Committee for Environment Canada had not been designated as of March 31, 1985.

1.2 Administrative Arrangements

The Steering Committee, with Mr. D. Kimmett as Chairperson, met a total of 6 times during 1984/85. The Technical Advisory Committee (T.A.C.) met only once in 1984/85, on February 19, 1985. The purpose of the (T.A.C.) meeting was to review the 1985/86 proposals for the scheduled Agreement projects and to provide advice on any additional work which they felt could be productively undertaken in 1985/86, the last year of the Agreement.

The names and addresses of the members of the Steering Committee and the Technical Advisory Committee are given in Appendix A.

Ms. L. McKerness was employed, on a part-time basis, as the Agreement Coordinator and as the Project Leader for Project 4.1, Public Awareness. She worked approximately three-fourths of the year in 1984/85.

1.3 Financial Arrangements

The total Agreement budget for 1984/85 was $210,000 of which $208,008.25 was spent. Table 1.1 shows the total cost shared expenditures incurred under the Agreement in 1984/85. Complete financial records were maintained for the purpose of possible future audits.

Table 1.1 1984/85 Budget and Expenditures, by Project

Project Number	Total Agmt. Project Budget	1984/85 Project Budget[2]	1984/85 Expenditures	Expenditures To Date
1.2[1]	100,000	12,500	12,048.76	12,048.76
1.3	40,000	-	-	38,069.01
2.1	60,000	-	-	52,540.27
2.2	42,000	-	-	29,423.62
2.3	40,000	20,000	20,000.00	52,576.38[3]
2.4	160,000	97,500	97,500.00	157,500.00
3.1	30,000	15,000	14,287.75	14,287.75
3.3	173,000	30,000	29,989.09	109,084.21
4.1	25,000	8,400	7,655.36	7,655.36
4.2	60,000	26,600	26,527.29	46,349.47
4.3	30,00	-	-	-
TOTAL	760,000	210,000	208,008.25[4]	519,534.83

NOTE:

1. Projects 1.1, 3.2, and 3.4 are not funded under the Agreement.
2. The amounts listed in this column differ from those in Schedule B of the Agreement. These amounts represent the budget approved for each project by the Steering Committee as recorded in the minutes of their meetings.
3. The Steering Committee redirected funds from Project 2.2 to Project 2.3 in 1982/83 as recorded in minute item 5.3.5.
4. There was an under-expenditure in 1984/85 of $1,991.75.

CHAPTER 2. PROGRAM 1

2.1 Project 1.1, Mercury in Water and Sediments

This project was one of the three non funded projects under the Agreement. It was part of an ongoing provincial government program which was conducted by the Department of Environment and Workplace Safety and Health. However, it was discontinued effective April 1, 1984. For a description of the program and its results, please see pages 5 and 6 of the 1983/84 Annual Report.

2.2 Project 1.2, Source and Material Balance

The original intent of this project was to approximate the distribution and destination of MERCURY[1] in the Agreement study area. However, as noted in the 1983/84 Annual Report, a rigorous study of a material balance of mercury is not possible. Therefore, a modified objective for this project was agreed upon; namely to investigate the potential sources of mercury in the study area. Specific objectives were:

1. To compile all available information on mercury in all sectors of the environment within the study area;
2. To compile information on known and potential point and non-point sources of mercury within the study area;
3. To evaluate the relative importance of each potential source; and
4. To identify gaps in existing information and recommend additional work which might remove some of the gaps.

Early in the summer of 1984, proposals were requested from a number of firms to undertake the required work under this project. In August, the firm of Agassiz Systems, Research and Technology Ltd. was selected as the successful contractor.

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1 Throughout this report, whenever a "technical" word appears for the first time, it will appear in capital letters. The meaning of these "technical" words will be found in the glossary at the end of the report.

The terms of the contract specified that the work program would consist of two main components; A. data compilation and analysis; and B. documentation and synthesis. Under component A, a comprehensive compilation and analysis of existing information was to be undertaken on mercury in the environment of the study area. The principal study area was defined as that part of northern Manitoba which is part of, or immediately adjacent to, Southern Indian Lake and the Rat-Burntwood River. However, in order to obtain background information for comparison purposes a larger, total study area was defined with limits approximately as follows: to the north, the Missi Falls outlet on Southern Indian Lake; to the west, upstream on the Churchill River, up to and including Reindeer Lake; to the south, upstream on the Nelson River, up to and including Sipiwesk Lake; and to the east, downstream on the Nelson River, up to and including Split Lake.

Two types of information were to be collected; potential point and non point sources of mercury to the study area, and recorded mercury levels in the various components of the environment, eg. fish, wildlife, water, etc. Of the two types of information, primary emphasis was to be given to the potential sources of mercury. The time series for the information collected was to extend from the most current data available to as far back as was possible. The principal source of information were to be personal interviews and a literature search, with all sources of information to be well documented.

Under Component B, the contractor was to provide a written report which was to include a clear, concise presentation of the data, a discussion section, recommendations, and a complete bibliography. With respect to the presentation of information on sources of mercury some estimate was to be given of the relative importance of each source, importance being defined in terms of quantity and bioavailabity of the mercury. The presentation on mercury levels was to be done in such a manner as to enable easy comparison of the same type of data between different years and different locations within the designated study area. In addition, the report was to include a discussion section on some of the gaps which have been identified in the existing knowledge base on mercury in the study area and recommendations on how to eliminate the identified gaps.

The total amount of the contract was not to exceed twelve thousand dollars ($12,000.00). A penultimate draft was to be ready by December 14, 1984.

The contract proceeded according to schedule with the penultimate draft circulated to Agreement participants for their review in mid-December. A presentation of the work was given by Agassiz at the January 17, 1985 "Work-in-Progress" meeting. The final report for this work will be released as one of the Agreement technical appendices. Some of the observations which were contained in the draft report included:

1. Lakes with average mercury concentrations in northern pike in excess of commercial standards are common within north-central Manitoba. In about 40% of the lakes for which data were available, average mercury concentrations in northern pike exceeded the standard for domestic sale, with about 8% exceeding the export standard. In contrast, data from northern Saskatchewan indicated that only 9% of the surveyed lakes exceeded the domestic standard. The median lake average mercury concentration in northern pike in northern Saskatchewan was only about half that for northern Manitoba.

2. The highest concentrations occured in water bodies along the Churchill River Diversion-Burntwood River system and in the region south and southwest of Lynn Lake. Below average concentrations occured in fish in lakes near Flin Flon and east of the Nelson River.

3. There was no evidence to indicate that significant quantities of mercury were transported into the region, either by human or natural agencies, and it was concluded that the elevated concentrations observed in fish were caused by factors which are internal to the region.

4. The bedrock in the region contains mercury in concentrations which are elevated with respect to most other regions in Canada of similar lithology. Particularly elevated values occur in association with sulphide minerals, and volcanogenic host rocks for sulphide mineralization are widespread.

5. A general association was apparent between lakes with elevated fish mercury concentrations and rock types which have good potential for sulphide mineralization.

6. Smelting operations appeared to have little or no general impact on mercury concentration in fish.

7. Active and inactive gold and base metal mining operations have had no identifiable effect on the mercury concentrations in fish in nearby lakes. None of the lakes with elevated fish mercury concentrations receive drainage from mine operations.

8. Water bodies which had experienced raised water levels due to impoundment or increased flow exhibited highly elevated fish mercury concentrations. This was especially notable along the Churchill Diversion Burntwood River system but elevated concentrations in other impounded water bodies in northern Manitoba were documented in Agassiz' report. It was concluded that many of the most elevated fish mercury concentrations may be attributed to impoundment. A general relationship between age of impoundment and average fish mercury concentrations was observed.

9. No relationship between water pH and fish mercury concentrations was found.

10. The mercury concentrations of lake bottom sediments in the region did not appear to be elevated, although very high values occured locally at sites which received drainage from mine tailings. No relationship between mercury concentrations in lake bottom sediments and fish could be demonstrated.

11. Forest fires may be an important factor in mobilizing mercury contained in vegetation and soils. (This conclusion was based on calculations which used 0.4 µg/g as a mean mercury content of BIOMASS. This value, obtained from an Environment Canada report entitled "Natural Inventory of Natural Sources and Emissions of Mercury Compounds", has subsequently been questioned as being 10-100 times too high for the biomass along the diversion route).

12. With the exception of impounded water bodies, the mercury contamination of lakes in north-central Manitoba is natural in origin and is sufficiently widespread to warrant continued study.

2.3 Project 1.3, Mobilization and Methylation

This cost shared project was funded under the Agreement only for the 1982/83 fiscal year. Preparation of the project report is now in progress. For a description of this project and its results, please see pages 7-13 inclusive of the 1983/84 Annual Report.

CHAPTER 3. PROGRAM 2

3.1 Project 2.1, Experimental Ecosystems

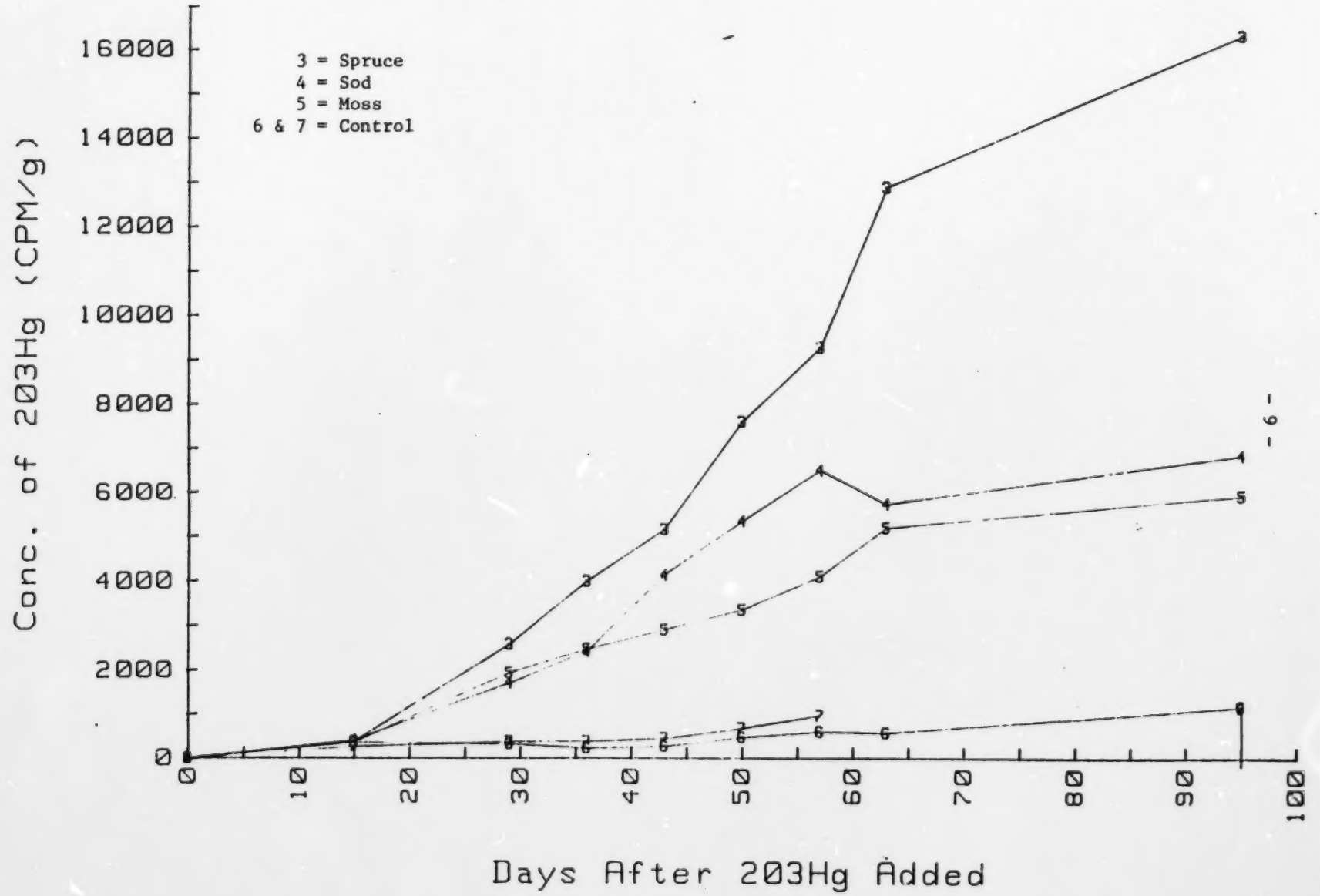
The intent of this project was to study the effects of changes in the aquatic environment associated with lake impoundment on the BIOACCUMULATION of mercury. The last year of funding under the Agreement for this project was 1983/84. However, the Department of Fisheries and Oceans provided funding in 1984/85 in order that some additional field experiments may be undertaken. LIMNOCORRALS were once again established in Southern Indian Lake. In each year of these experiments the limnocorrals are positioned in the same bay but in slightly varying locations within that bay. As in previous years the limnocorrals were fished out, yellow perch were added and a RADIOACTIVE ISOTOPE of mercury was added as mercuric chloride.

From the results of previous years' experiments, it was known that the addition of moss to the limnocorrals always resulted in significantly enhanced uptake of radioactive mercury in yellow perch compared to the controls. It was also known that sediment treatments could also stimulate uptake of radioactive mercury but not to the same extent as added moss did. However it was not known what effect other kinds of material would have.

In the summer of 1984, the same experiment involving the moss treatment which had been conducted in previous years was repeated. Each year the results of the moss treatment have been essentially the same. The results of this experiment served as a comparison for the results of the experiments involving other added material.

Sod material from southern Manitoba was obtained to see what effect ground cover from another, different PEDOLOGICAL regime might have on the bioaccumulation of mercury. The results showed that the sod enhanced the accumulation of radioactive mercury in yellow perch at least to the extent of the added moss, if not greater (see Figure 3.1). A spruce treatment also enhanced the accumulation of radioactive mercury. (The amount of spruce or sod added to each experiment was scaled to represent a reasonably realistic situation). Thus it is obvious that a broad range of organic material and soils can enhance METHYL-MERCURY accumulation in fish.

FIGURE 3.1. 1984 203Hg Uptake by Perch Muscle



3.2 Project 2.2 Bioaccumulation Processes

The purpose of this project was to study the mechanisms of mercury transfer between the bottom sediment reservoir and the fish population. This project was funded under the Agreement in 1982/83. A report on this project is now in progress.

Samples were taken from a number of sites in the system with different sedimentation regimes. The sites were located as follows: Granville Lake, South Bay, Central Mynarski, Rat Lake, and two each in Notigi and Long Bay. Tentative conclusions from this project include:

1. There was a high correlation between total mercury in the sediments and the ORGANIC content of the sediments. This relationship suggests that as the BENTHOS feed on the organic content of the sediments, this is also their source of mercury.

2. There is no correlation between total mercury in benthos and total mercury in sediments.

3. There seems to be a growth effect on mercury accumulation. Comparison of specimens of roughly the same size but from locations of differing food availability showed a greater concentration of mercury in the body burden where food resources were less readily available.

4. There seems to be an increase of mercury in the body burden from the lower TROPHIC LEVELS of the food chain to the higher levels.

3.3 Project 2.3 Biogeochemistry of Sediments

The objective of this project was to investigate the relationships between the environmental effects of impoundment and the forms, abundance, and bioaccumulation of mercury. The research program initiated in the summer of 1983 was continued throughout 1984 with essentially no change in experimental design or methodology.

In June 1984, fresh samples of bottom sediments were collected from two sites in Methyl Bay (one was a near-shore flooded location and the other site was an offshore "normal" mud bottom location), and from two lakes not affected by flooding - Granville and East Mynarski. The samples were analyzed chemically and were used for experiments on the effects of selected environmental variables on the METHYLATION of INORGANIC BIVALENT mercury ($Hg\ Cl_2$) and the DEMETHYLATION of methyl mercury (CH_3Hg^+) acetate. Except for certain experiments performed for the purpose of comparing different field sites, sediment from East Mynarski Lake was used as the source of methylating and demethylating MICROBES.

Sediment-water slurries with added inorganic or methyl mercury were incubated at room temperature under different conditions (eg. with an atmosphere of nitrogen or air, with and without added organic SUBSTRATES, with and without clay, etc.) for varying lengths of time up to three weeks and then analyzed. The principal results and interpretations are summarized as follows:

1. Methyl mercury and total mercury concentrations, methyl mercury/total mercury ratio, and organic content, as well as rates of mercury methylation and rates of carbon dioxide and methane production by microbes, were much higher in samples from recently flooded land than in regions unaffected, or less strongly affected, by flooding. Accelerated methylation in flooded areas is due primarily to stimulation of HETEROTROPHIC MICROBIAL activity by decomposing remains of submerged terrestrial plants. (Elevated concentrations of INORGANIC mercury derived from diffuse natural terrestrial sources may be a contributing factor but appear to be of secondary importance).

2. Pulverized moss and different kinds of algae added to sediments caused a marked increase in rates of methylation.

3. All other conditions being equal, methylation of mercury was much more efficient under mildly ANAEROBIC conditions than under AEROBIC conditions, but occurred under both sets of conditions. Methylation was moderately suppressed by ferrous sulfide, and totally suppressed by hydrogen sulfide gas, possibly because of immobilization of mercury as an insoluble sulfide.

4. In the methylation experiments, methyl mercury levels generally increased with time for about a week and then declined, indicating destruction (demethylation) of the methyl mercury. Thus in the microbial community of the sediments, methylation is counterbalanced to a greater or lesser degree by demethylation.

5. Demethylation of mercury occurred under both anaerobic and aerobic conditions, but efficiency of demethylation was greater in an anaerobic environment. Addition of moss caused a large increase in demethylation under an atmosphere of air but caused a decrease under nitrogen. Demethylation efficiency was greatest under nitrogen with no added moss, and was least under air with no added moss.

6. The optimum pH range for both methylation and demethylation was approximately 7-8. Buffering of sediments by the addition of calcium carbonate increased the rate of methylation.

7. Addition of Pleistocene shoreline clay to slurries containing sediment in its unbuffered native state stimulated mercury methylation by the sediment microflora, apparently because of pH buffering by carbonates present in the clay. In further experiments designed to test effects of clay other than pH buffering, all slurries, including controls, were artificially buffered with calcium carbonate to maintain uniform, neutral pH conditions. Surprisingly, it was found that the clay had little or no effect on methylation but greatly accelerated subsequent demethylation of the methyl mercury produced. Clay whose iron/manganese coatings had been removed inhibited both methylation and demethylation, but removal of organic coatings had no effect. Thus, effects of clay minerals and associated colloids are complex, and further work is required. The research on this aspect of the mercury problem is continuing.

3.4 Project 2.4, Limnological Survey (and Fish Surveys)

In 1984/85 all work being conducted by the Department of Fisheries and Oceans at Southern Indian Lake - namely the LIMNOLOGICAL survey being conducted by Dr. R. E. Hecky and the fish surveys at Southern Indian Lake and Issett Lake being conducted by Dr. R. A. Bodaly - were amalgamated for purposes of administrative and financial management into Project 2.4. Both aspects of this expanded project will be discussed in this section.

The general objective of the limnological survey was to determine if the future evolution of Southern Indian Lake and Notigi, in terms of its impact on increased mercury concentrations, can be assessed by looking at older reservoirs in northern Manitoba. More specifically, the objective was to follow the cycle of total mercury availability in reservoirs of different ages and compare their cycles to control lakes, to measure different LIMNOLOGICAL PARAMETERS such as temperature and oxygen, and to measure the relative rates of methylation and demethylation at different locations and different times in the reservoirs.

A number of reservoirs were selected for study - Southern Indian Lake, Notigi, Sipiwesk, Stephens, Reindeer and, as controls, Granville and East Mynarski. The ages of the reservoirs varied, with Reindeer Lake the oldest. Two different locales were selected in Southern Indian Lake and Notigi and one locale each for the remaining lakes and reservoirs. Each locale had three sites sampled six times over the summer. In early August an additional three sites were added at each locale to get a better spacial view of the methylation and demethylation rates...

Because 90-100% of mercury in the fish is methyl mercury it was recognized that the key to look for is the transformation of mercury to methyl mercury in the environment. It was known from documented work on methylation that only Hg^{2+} is methylated, that methylation always involves a cobalt-methyl bond, and that whether the reaction occurs aerobically or anaerobically, it is always bacteria related.

To measure methylation, a radioactive tracer of ^{203}Hg is added. The percentage of mercury added that is transformed to methyl mercury is measured in grams/hour. Similiarly radioactive methyl mercury is used to measure demethylation, by measuring production of C^{14} methane. Again the results are given as % of Hg added in grams/hour. Both reactions are examined in the same sample. This is not an absolute method since it is not possible to measure methyl mercury. However a measure of the methylation/demethylation balance can be obtained and compared for different sites over time and between different reservoirs.

The methylation/demethylation (M/D) balance was measured at all sites - which included geographic areas that had been flooded and those which had always been a part of the lake sediment (see Figure 3.2). Some uncertainty was encountered in older reservoirs in ensuring that it was organic detritus that was obtained for the M/D balance measurements, and not sediment that have been deposited prior to impoundment.

A ZOOPLANKTON tow from inshore to offshore was made at each site in order to measure the mercury in the zooplankton. The mercury in the zooplankton was used as an indicator of the total availability of mercury in the reservoir over time of year and over physical conditions. The total mercury in zooplankton was measured in microgram/gram of biomass.

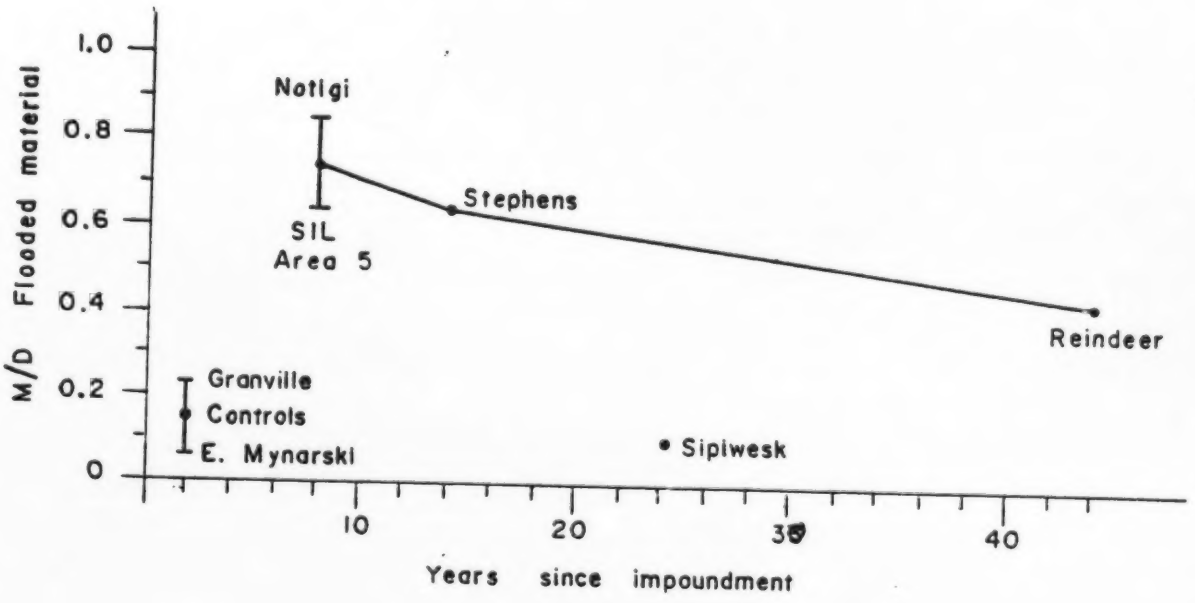
The measurement of mercury in zooplankton showed fairly low values during the warming period (up to July) and then a sudden increase in mercury in early to mid August (see Figure 3.3). (Water temperature which is very important to the whole process peaked in early July and August).

Preliminary interpretation of these results is that the availability of total mercury is cyclical in reservoirs and lakes. There is a marked difference in seasonal availability of mercury, with a dramatic increase in all sites occurring in August.

It was also observed that the control lakes had the highest concentration of mercury in the zooplankton. The relative amount of flooding and the age of the reservoir have no apparent effect on mercury concentrations in zooplankton.

The methylation/demethylation ratio is mainly driven by the methylation rates. There is a pronounced seasonality in the methylation rates, with the rates being very low in early summer, fall and winter. Very high rates of methylation occur in early August at maximum water temperature and when mercury is becoming available in the water column (as indicated by measured mercury concentrations in zooplankton). There does not seem to be a well defined seasonality to the demethylation rates.

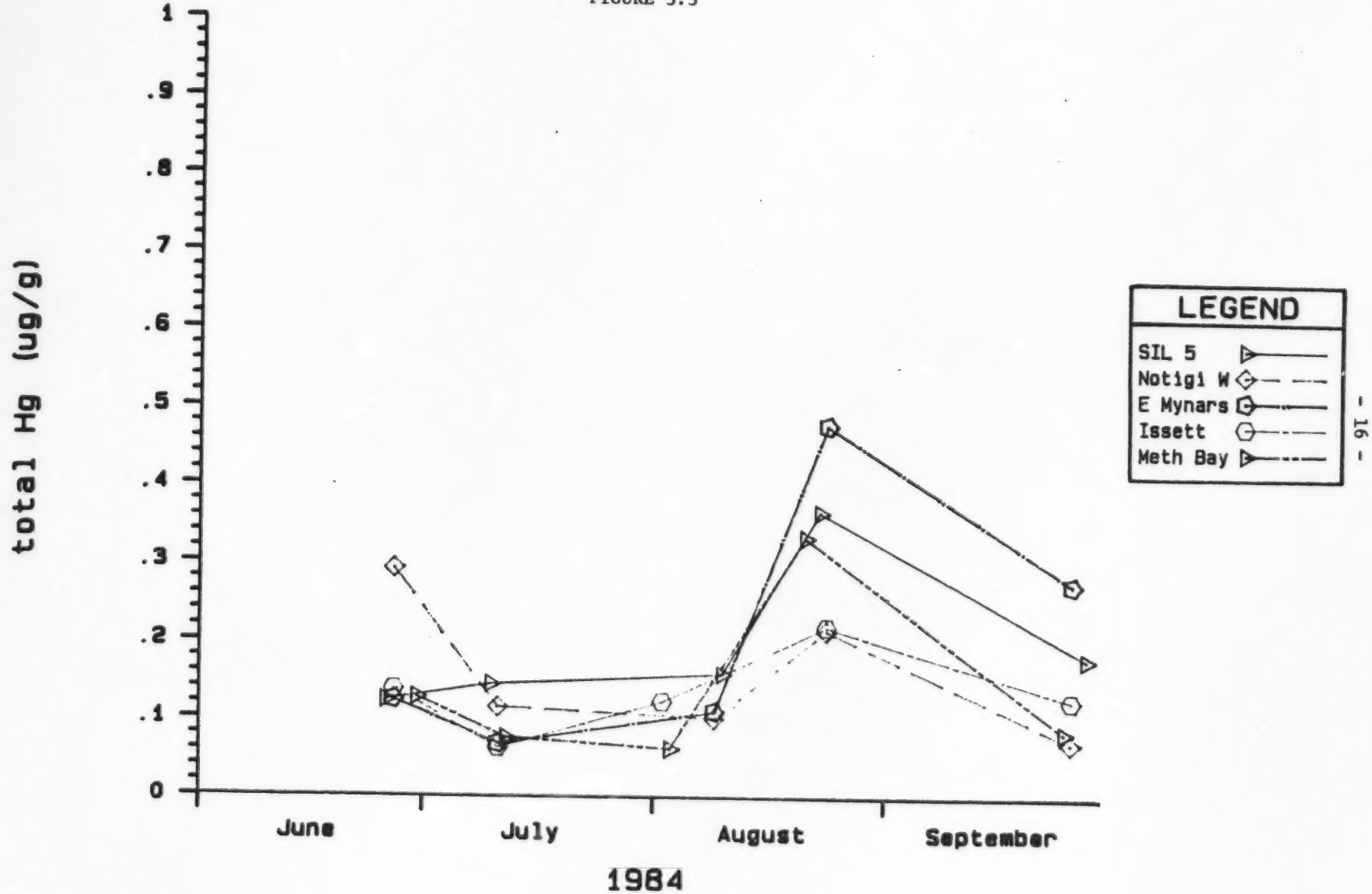
FIGURE 3.2. Relationship between Reservoir Age and Peak Methylation to Demethylation Ratio (M/D) of Flooded Terrestrial Material and Comparison with M/D of Littorial Sediments in Control Lakes.



NOTE: The site sampled in Sipiwesk Lake was subsequently discovered not to have been in the zone of flooded terrestrial material.

TOTAL MERCURY IN NETPLANKTON 1984 RESERVOIR SURVEY (Mesh Size 73u)
02-12-1985

FIGURE 3.3



In summary it appears that there is adequate mercury at every site studied to have a mercury problem. The same processes of methylation and demethylation occur at all sites. However, the magnitude of the methylation of the methylation/demethylation ratio is determined by bacterial growth which is higher in reservoirs because of the high organic loading in them.

Dr. R. A. Bodaly conducted the fish survey program at Southern Indian Lake and Issett Lake as part of Project 2.4. The intent of this portion of the project is to monitor the mercury content of the domestically harvested fish population.

In 1984 fish were collected at four sites in Southern Indian Lake, namely, South Bay, Camp 9, Area 4, and Area 5. A fifth site, Issett Lake, which is at the upper end of Nogiti Lake was also sampled. Six species of fish were sampled at each site, whitefish, pike, walleye, cisco, longnose sucker, and burbot. The fish were weighed and measured. The tissue samples were removed, frozen, and shipped to the laboratory for total mercury determination. The same size of GILL NET was used to collect the fish as in previous surveys. In addition the fish are collected at approximately the same time of the year each year. The results of the 1984 program are shown in Table 3.1.

One observation of this program is that there doesn't seem to be any CORRELATION between size of fish and mercury concentration when the system is disturbed. Before impoundment almost all samples taken showed a correlation between mercury content and the size of the fish and now, 7-8 years after impoundment took place, this correlation seems to be re-establishing itself. However, in the years immediately following impoundment there tended to be very few correlations between mercury concentration and fish size.

Another observation is that there does seem to be a food chain effect since the predators (eg. pike) have higher levels of mercury in them than do non predators, such as whitefish. Feeding near shore where mercury levels in food may be higher than in areas further offshore, may also be a factor in influencing the mercury levels in fish.

Table 3.1 1984 Mercury Concentrations from D. F.O.'s Fish Survey Program
n = sample, Hg = mean muscle mercury concentration (µg/g), and FL = mean fish length (mm).

Site	Parameters	Whitefish	Northern Pike	Walleye	Cisco	Longnose Sucker	Burbot
South Bay	n	38	36	25	32	1	1
	Hg	0.16	1.18	0.65	0.22	0.13	0.19
	FL	379	548	385	301	464	495
Issett Lake	n	47	27	23	25	-	-
	Hg	0.23	1.09	0.46	0.35	-	-
	FL	405	609	284	348	-	-
Camp 9	n	46	46	25	50	41	12
	Hg	0.09	0.57	0.40	0.19	0.10	0.22
	FL	312	484	365	293	422	484
Area 4	n	47	25	25	21	25	2
	Hg	0.10	0.63	0.45	0.13	0.13	0.36, 0.18
	FL	379	500	433	285	418	543, 568
Area 5	n	50	31	26	18	5	6
	Hg	0.20	0.50	0.58	0.19	0.20	0.48
	FL	408	472	386	242	463	578

CHAPTER 4. PROGRAM 3

4.1 Project 3.1, Mercury in Fauna

The objective of this project is to monitor the mercury levels in the FAUNA from the Agreement study area. This project was funded under the Agreement for the first time in 1984/85. However some limited data for mercury levels in mink and otter from the Agreement study area are available for 1980 and 1983. In addition some data are available on mercury levels in these animals from other areas of Manitoba for comparison purposes.

In 1984/85 approximately 200 mink and 50 otter were collected from the Agreement area. The carcasses of these animals were obtained from trappers who trap in the registered traplines within the Agreement area. Each particular trapline covers a fairly large area but each individual mink would likely not range more than 3 km. The mink would be eating approximately 60-70% of their diet as fish with another 10% of their diet consisting of other food taken directly from the water. While it is not known exactly where within each trapline each animal was caught, it is felt that the known location of the trapline within the Agreement area, the high percentage of aquatic food in their diets, and the limited mobility of the mink, make the mink a good indicator of mercury levels within the Agreement area.

Tables 4.1 and 4.2 present the mercury concentrations in the brain, liver and kidney tissues of mink according to the drainage area where the animals were sampled. The concentrations in the three tissues were significantly correlated with each other. There was no significant correlation between the mercury concentration and either age, sex or weight of the animals. This lack of correlation is likely the result of the preponderance of one age group, since approximately 80% of the mink sampled were under two years old. (This is a common occurrence in an exploited population.)

TABLE 4.1 Total Mercury in 1984 Mink Sample (µg/g Freeze-Dried[3] tissue; Mean ± S.D. (range)).

AREA	n	BRAIN	LIVER	KIDNEY
PEMBINA	32	1.044 ± 0.734 (0.13 - 3.33)	4.206 ± 3.785 (0.36 - 18.2)	3.451 ± 2.159 (0.56 - 7.74)
RAT[2]	25	1.682 ± 1.184 (0.32 - 4.02)	6.394 ± 5.589 (1.11 - 19.5)	4.885 ± 3.736 (0.94 - 13.7)
RED	6	1.238 ± 0.403 (0.45 - 1.50)	3.968 ± 2.23 (1.69 - 7.82)	3.625 ± 1.098 (1.74 - 4.65)
BURNTWOOD	12	5.15 ± 3.782 (1.93 - 12.0)	18.712 ± 11.318 (5.14 - 42.4)	10.887 ± 6.672 (4.46 - 23.6)
SOUTH INDIAN	18	5.356 ± 4.954 (0.29 - 19.7)	16.734 ± 18.967 (2.09 - 74.7)	13.657 ± 10.937 (1.69 - 48.1)
SPLIT LAKE	14[1]	3.171 ± 2.357 (0.96 - 7.75)	10.372 ± 8.193 (2.32 - 26.3)	7.586 ± 6.573 (1.72 - 24.5)
ASSINIBOINE	2	0.535 (0.34 - 0.73)	1.54 (1.46 - 1.62)	1.48 (1.17 - 1.79)

[1] n = 12 for Liver and Kidney.

[2] Rat River in southern Manitoba.

[3] To calculate micrograms per gram wet weight, multiply by 0.41 for liver, 0.43 for kidney, and 0.33 for brain.

TABLE 4.2. Total Mercury in 1983 Mink Sample (ppm Freeze-Dried[4] Tissue; Mean ± S.D. (range)).

AREA	n	BRAIN	LIVER	KIDNEY
SOURIS	18	0.389 ± 0.30 (0.15 - 1.32)	1.277 ± 1.02 (0.42 - 4.46)	1.53 ± 1.10 (0.39 - 4.45)
RED	51	0.850 ± 0.953 (0.15 - 2.18)	4.458 ± 7.36 (0.43 - 17.5)	3.65 ± 3.33 (0.80 - 8.96)
WHITEMUD	9	1.007 ± 0.934 (0.16 - 3.05)	4.34 ± 4.11 (1.07 - 12.0)	3.02 ± 1.40 (1.19 - 5.26)
PEMBINA	27	1.053 ± 1.151 (0.10 - 4.35)	3.87 ± 4.38 (0.29 - 17.4)	2.62 ± 2.74 (0.42 - 10.9)
BOYNE	8	1.505 ± 1.152 (0.15 - 3.44)	5.05 ± 4.66 (0.34 - 11.8)	4.55 ± 3.42 (0.67 - 9.30)
ASSINIBOINE	12	1.554 ± 1.063 (0.25 - 3.19)	6.79 ± 5.08 (0.42 - 19.2)	4.86 ± 3.15 (0.86 - 8.87)
RAT[3]	22	1.753 ± 1.268 (0.17 - 4.12)	6.35 ± 4.68 (0.35 - 18.2)	5.67 ± 4.0 (0.59 - 13.2)
BURNTWOOD	6	2.207 ± 1.222 (0.88 - 4.04)	8.34 ± 5.51 (2.67 - 17.2)	6.08 ± 3.14 (2.79 - 10.5)
SPLIT LAKE[2]	13	2.491 ± 1.795 (0.34 - 6.45)	9.21 ± 5.73 (1.4 - 18.5)	6.45 ± 3.0 (1.21 - 12.0)
NELSON	7	2.734 ± 2.247 (0.34 - 6.45)	9.96 ± 6.23 (1.4 - 18.5)	6.77 ± 4.03 (1.21 - 12.0)

[1] for Brain n = 4

[2] Composite of Burntwood and Nelson

[3] Rat River in southern Manitoba

[4] To calculate micrograms per gram wet weight, multiply by 0.41 for liver, 0.43 for kidney, and 0.33 for brain.

Southern watersheds are included in the tables for comparison. The mercury levels in tissues of mink from the Agreement area are significantly higher than in mink from the southern watersheds. Within the Agreement area, the three sampled areas were not significantly different from each other. However the mercury concentrations were progressively lower in the order South Indian Lake, Burntwood River, Split Lake; that is, the farther downstream from the reservoir, the lower the concentration.

The mercury concentrations in the brain tissues in all southern samples were low. In the Agreement area, some individual minks approached the brain mercury level of 7.0 ppm (wet weight) the level at which intoxication occurs. (See Figures 4.1, 4.2 and 4.3). Of the samples analyzed to date, two mink in the Burntwood area had brain mercury concentrations of 4.0 ppm, and in the South Indian Lake area, the highest concentrations were 4.4 and 6.5 ppm. In the Split Lake area, which had the lowest mean concentration in the Agreement area, the range was 0.32 to 2.56 ppm wet weight.

One important observation which can be made from this data regarding the mink in the Agreement area is that as a group they are at present not in danger from mercury poisoning. While the mercury levels in mink from the Agreement area are elevated in comparison to mink in other parts of Manitoba, they are, with a few exceptions, well below the level at which mercury intoxication appears.

4.2 Project 3.2, Commercial Fish Survey

In the previous annual reports for this Agreement, a description of the objectives and methods of this project were given. The reader is referred to those reports for such details. One point that should be restated is that Project 3.2 is not cost-shared under the Agreement; it is part of an on-going departmental program of Fisheries and Oceans (DFO).

As noted in the 1983/84 annual report, the emphasis, since 1975, in the DFO commercial fish survey program with respect to mercury has been to monitor those lakes which have been identified as problem lakes. Table 4.3 shows the results of the mercury analysis for these lakes for 1984/85. The commercial

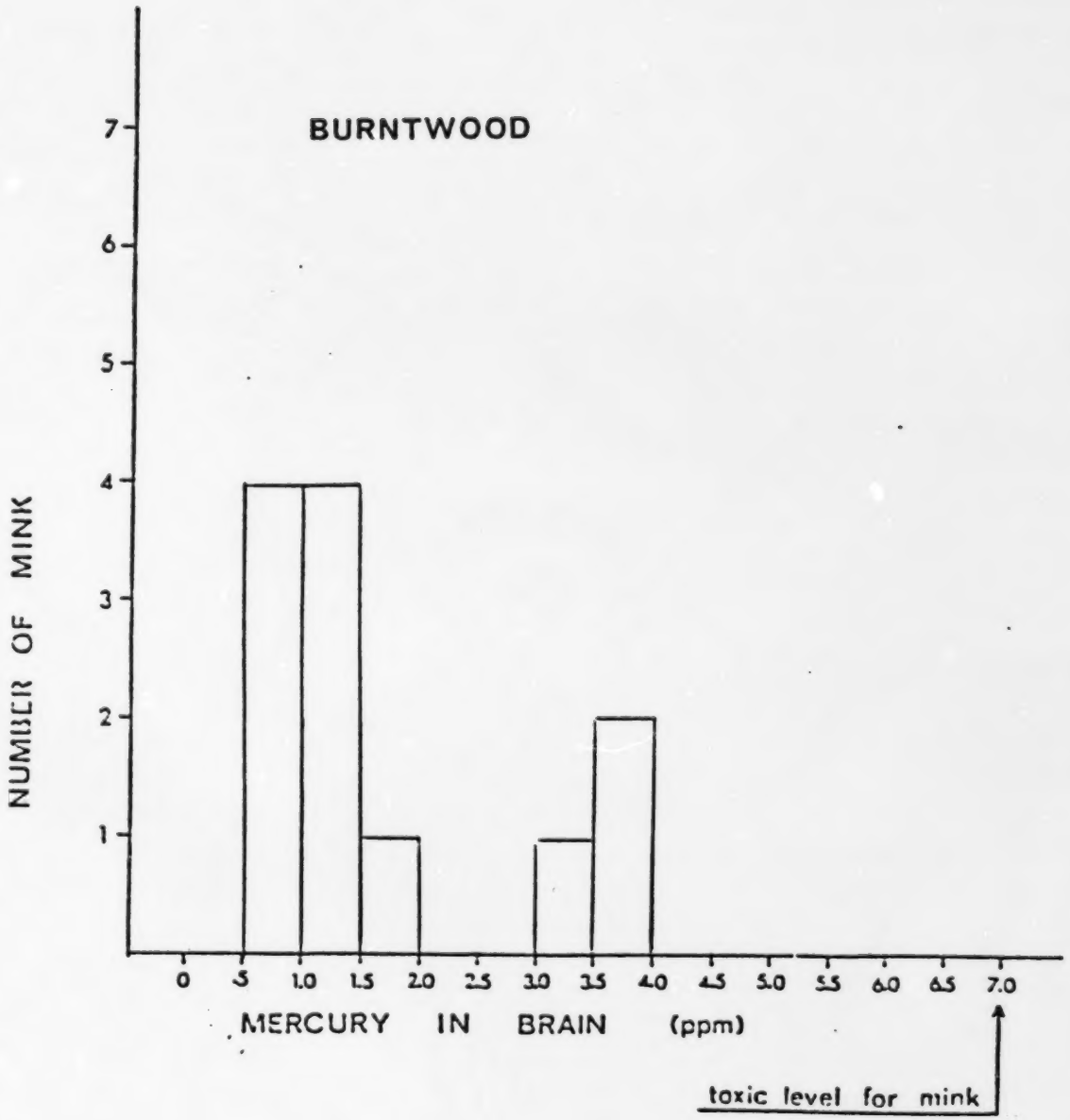


Figure 4.1. Total mercury in mink brain (ppm wet weight). 1984

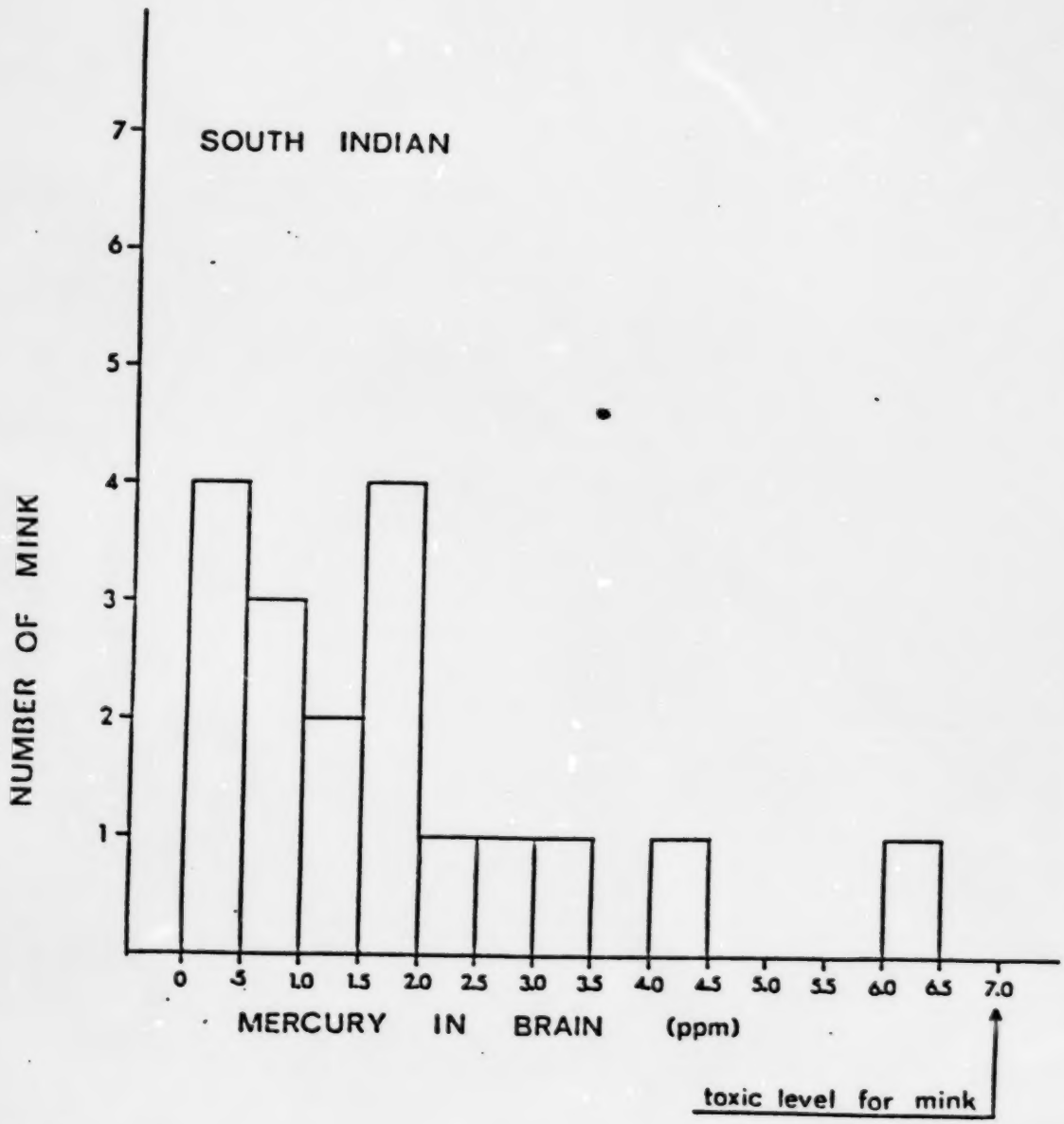


Figure4.2. Total mercury in mink brain (ppm wet weight). 1984

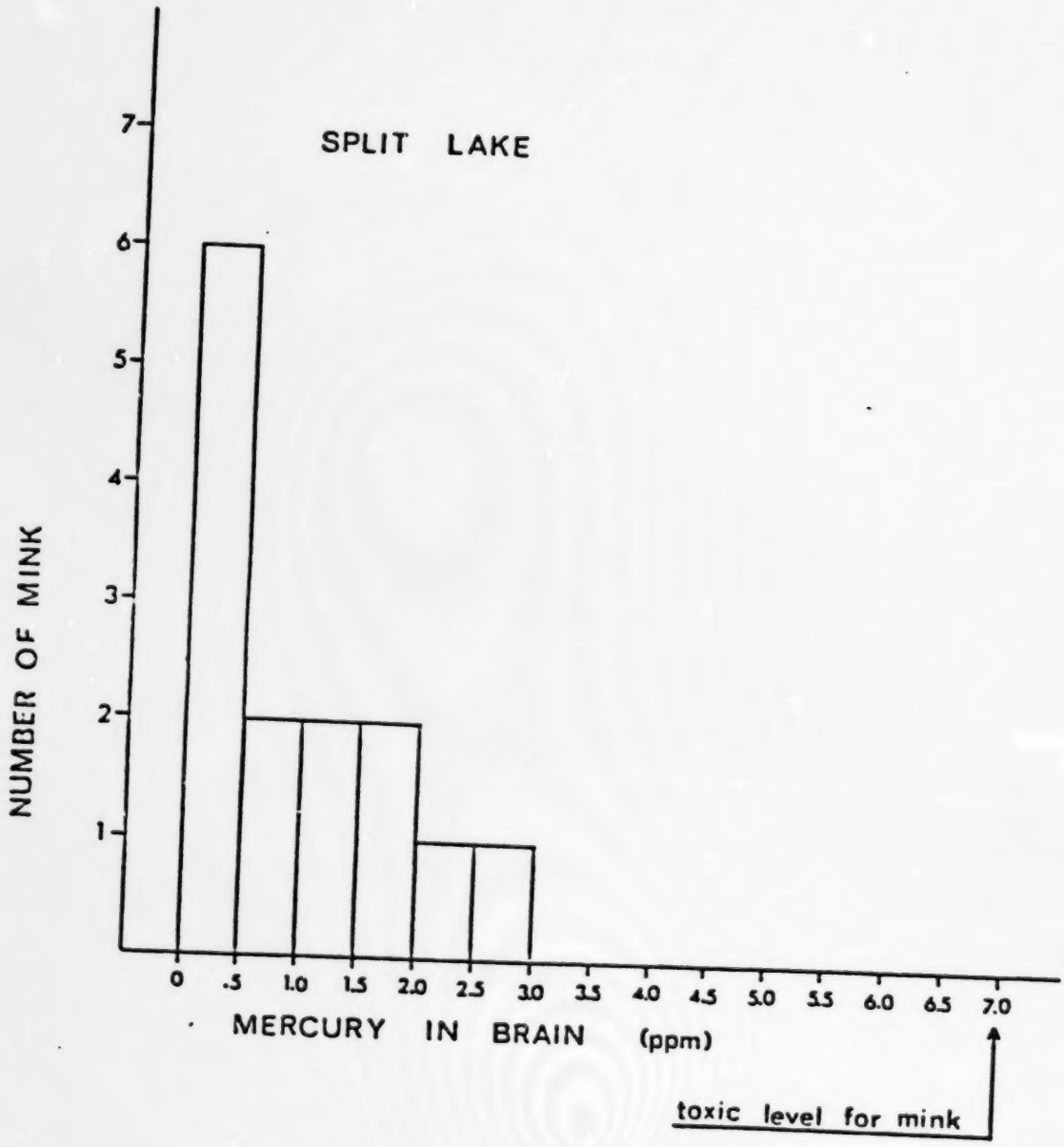


Figure 4.3. Total mercury in mink brain (ppm wet weight). 1984.

TABLE 4.3 Mercury Results for 1984 Calendar Year for Selected Lakes, Commercial Fish Monitoring Program.

Lake	Species	# Samples	Mean ppm	Range
Apussigamasi	N. pike	6	1.70	1.23 - 2.32
Beatty	N. pike	5	1.02	0.33 - 1.41
	pickerel	3	1.31	1.22 - 1.38
Beaucage	N. pike	3	1.13	1.00 - 1.24
	pickerel	3	1.03	0.66 - 1.32
Drunken	N. pike	2	0.64	0.52 - 0.77
Issett	N. pike	6	1.08	0.80 - 1.38
	pickerel	3	1.33	1.23 - 1.46
Mynarski East	N. pike	5	0.39	0.32 - 0.50
Nelson River	N. pike	14	0.83	0.43 - 1.65
Osik	N. pike	1	1.43	-
	pickerel	1	0.99	-
Sipiwesk	N. pike	13	0.76	0.45 - 1.30
	pickerel	1	0.18	-
Southern Indian	N. pike	15	0.97	0.63 - 1.63
	pickerel	1	0.42	-

fish from most of the lakes in or near the Agreement area, including many of the problem lakes listed in Table 4.3, could still be marketed in the United States during 1984/85.

Of the total commercial fish landed from the lakes in or near the Agreement area only a very small percentage were destroyed because of mercury. In recent years about 2 million pounds of fish have been caught, each year, from lakes in an area called the Northern Flood Agreement Area, which is larger than and encompasses all of the Canada-Manitoba Mercury Agreement study area (See Table 4.4 for a listing of these lakes). Of these 2 million pounds, approximately 8000 pounds or .4% were destroyed because of mercury problems in the last 2 years. This represents an improvement from the years 1980-1983 when 18,000-24,000 pounds or .9 - 1.2%, of the fish were destroyed because of mercury.

There are a couple of reasons for this improvement. Some of the lakes along the diversion, where mercury levels in fish were elevated, are no longer fished. Better size grading of fish by fishermen on some lakes where mercury levels in fish are a concern has resulted in a higher percentage of smaller sized fish in the total amount of fish being offered for commercial sale. (Generally almost all the smaller sized fish have mercury levels below the rejection limit).

All of the fish rejected are walleye or northern pike. Whitefish have not been a problem. Data from other projects to date shows that it is only the whitefish that has experienced a reduction in mercury levels in recent years. Therefore the improvement in the rejection rate of fish because of mercury is as a result of selective fishing and not because of declining mercury levels in the fish.

Approximately 80% of the commercial fish catch from the Northern Flood Agreement area are sold in the United States. This is due to economic factors. Since the tolerance level for mercury in fish in the United States is 1.00 ppm (compared to the Canadian limits of 0.5 ppm), the impact of elevated mercury levels on the commercial fish catch has not been as serious as it might have been if the United States tolerance limit for mercury had been the same as Canada's.

Table 4.4 Northern Flood Agreement Area Lakes as of August 30/84

Aiken River
Assean
Baldock
Barrington
Bear
Burntwood River
Butnau
Cross
Crying
Cygnet Group
Drunken
Footprint
Gauer
Granville
Gull
Gunisao
Holmes
Jack River
Koskotto
Kiskittogusu (Grassy)
Leftrook
Limestone
Limestone Point
McBride
McLeod
Melvin
Molson
Moosenose
Mynarski East
Mynarski West
Mystery
Nelson River
Northern Indian
Notigi
Opachaunau
Osik
Paint
Pipestone
Playgreen
Rat
Sandy
Settee
Sipiwesk
Southern Indian
Split
Stephen
Threepoint
Utik
Walker
Wapisu
Waskaiowaka
Wuskwatim

4.3 Project 3.3, Fish Surveys and Fish Eating Guide

All work under Project 3.3 in 1984/85 was conducted by the Department of Natural Resources. (The fish surveys conducted by Dr. D. Bodaly in 1984/85 were completed under Project 2.4). The objective of Project 3.3 is to determine mercury levels in fish along the diversion route.

Analysis of the results of the 1983/84 program, which was the first year of data for this project, has provided the following observations:

1. Mean mercury levels in whitefish sampled along the diversion route in 1984/84 were below 0.5 ppm.
2. Walleye generally tended to have higher mercury levels than pike of the same size. This observation is based on the average mercury levels per kilogram of fish of both species.
3. Lakes which have been flooded showed high mercury levels in the predatory fish.
4. Notigi Lake which experienced more flooding than lakes below the Notigi control structure, such as Wapisu, Threepoint and Footprint, often had mean mercury levels in fish that were lower than those for the same species in the other lakes. This may be due to migration and subsequent mixing with fish from Southern Indian Lake. Southern Indian Lake fish generally have lower mercury levels than fish along the diversion route.
5. At the lower end of the diversion route, the mercury levels in fish were lower. However, there was quite a difference in mercury levels between Split and Stephens Lakes. Higher levels of mercury were found in fish from Stephens Lake which had experienced more flooding than had Split Lake.

In 1984/85 an attempt was made to sample the same lakes as in 1983/84, using the same sampling methods. Sampling was concentrated on whitefish, sauger, northern pike, and walleye since these are the important commercial species and the species most likely to be consumed by residents along the diversion route. Table 4.5 summarizes the results of the 1984/85 sampling program.

Table 4.5 Mean mercury ($mg.l^{-1}$), length (mm) and weight (gm) of various fish species sampled from lakes along the Churchill River Diversion Route and below River, 1984.

Lake	Parameters	Whitefish	Walleye	Sauger	Northern pike	Cisco	White sucker	Longnose sucker	Shorthead redhorse sucker	Mooneye	Goldeye	Yellow perch	Freshwater drum	Burbot
Kamakuwigamak	n	53	51		52	41	1							
	Hg	0.23	1.84		1.99	0.33	0.48							
	Fl	358	369		671	267	440							
	Wt	810	700		2740	370	1260							
West Nynaraki	n	52	49		51	29	10	9				2		4
	Hg	0.14	0.95		1.20	0.28	0.26	0.22				0.09		0.10
	Fl	358	363		625	321	402	435				143		426
	Wt	970	670		2250	560	1110	1360				40		600
Rat	n	50	65	2	52	30	17					4		11
	Hg	0.26	1.55	2.08	1.86	0.47	0.50					0.38		0.51
	Fl	333	327	295	601	290	415					212		522
	Wt	730	530	230	1920	420	1180					170		1160
Macheewin	n	50	44	20	57	27	38					24		1
	Hg	0.08	0.36	0.48	0.56	0.22	0.11					0.11		0.11
	Fl	354	352	276	522	245	350					168		494
	Wt	710	590	210	1100	300	750					70		840
Usik	n	58	51		60	38	34					6		4
	Hg	0.19	0.79		1.15	0.38	0.33					0.32		0.49
	Fl	370	343		498	305	376					239		518
	Wt	860	650		1180	510	880					250		1250
Footprint	n		54	7	51	32	28	1				9		1
	Hg	N/A	1.13	1.23	1.02	0.29	0.31	0.36				0.36		0.41
	Fl		379	306	444	274	402	384				243		656
	Wt		650	320	690	350	930	660				250		2330
Threepoint	n	51	54	17	51	31	33	9			2	4		2
	Hg	0.25	1.15	1.49	1.57	0.29	0.45	0.53			0.72	0.47		0.25
	Fl	361	351	301	561	302	404	433			359	243		392
	Wt	770	580	290	1530	520	1030	1230			550	250		560
Muskwatin	n	56	57	51	38	32	32	7				32		5
	Hg	0.20	0.66	1.13	1.02	0.25	0.21	0.34				0.30		0.35
	Fl	339	367	244	450	323	359	386				269		541
	Wt	810	650	150	790	620	770	1000				360		1230
Apussigamasi	n	33	54	20	53	40	45	31	10	30		1		1
	Hg	0.32	1.05	1.49	1.13	0.31	0.38	0.46	0.41	0.24		0.28		0.14
	Fl	369	291	323	486	253	375	438	382	231		185		188
	Wt	860	420	370	1150	310	930	1350	860	180		110		90
Split	n	29	70	48	56	29	28	6	1	31	4	27	1	
	Hg	0.07	0.38	0.41	0.31	0.06	0.12	0.24	0.08	0.16	0.46	0.10	0.21	
	Fl	327	353	268	520	228	351	385	342	268	355	178	448	
	Wt	690	550	230	1200	230	830	770	550	300	540	110	1410	
Stephens	n	40	70	15	44	26	15	32		30				
	Hg	0.21	0.70	0.75	1.47	0.21	0.15	0.22		0.17				
	Fl	352	341	313	675	233	379	364		229				
	Wt	950	690	380	2485	210	1000	720		160				

*Mean lengths and mean weights rounded to nearest mm and 10 gm, respectively. N.A. - data not available.

Analysis of the 1984 mercury results so far are inconclusive as to whether the level of contamination rose or declined from the previons year (1983). However, one interesting observation has emerged. Comparisons of mercury levels in pike of standardized sizes from the diversion route lakes over the period 1976-1984 show an increasing trend in mercury concentrations. Similar trends were not evident in Split or Sipiwesk Lakes over a longer period; mercury levels here tended to remain the same throughout the 1972-1984 period. Comparable observations were made for walleye.

4.4 Project 3.4, Mercury in Hair of Native People

In 1984/85, the Federal Department of Health and Welfare was again involved in taking hair and blood samples for mercury analysis from the native people living in the communities along the diversion route. As was noted in previous annual reports this project is not cost shared under the Agreement.

The same sampling and analysis procedures were employed this year as in previous years. For a detailed description of these procedures, the reader is referred to the 1983/84 Annual Report. The communities of South Indian Lake, Nelson House, Norway House, Split Lake, York Landing and Cross Lake were again offered a 100% voluntary testing program for all residents. In addition Health and Welfare Canada sampled 10% of the population of 11 other reserves in Manitoba. Annual retests for mercury analysis are being conducted for all individuals with reported mercury levels over 20 ppb and dietary advice provided to reduce their mercury intake. It is hoped that by the end of 1986 all Native communities in Manitoba will have had a least 10% of their populations sampled for mercury. The most current results of this program appear in Table 4.6.

Table 4.6

Results of the Mercury Monitoring Program
in Six Northern Communities from
July 1, 1983 - March 31, 1985

Communities	Total # Samples	0-20 ppb	20+ - 50 ppb	Ranges Over 50 ppb	Over 100 ppb
Cross Lake 2079 - 10%	Hair 211 Blood 0	204 (97%)	7 (3%)		
Nelson House 1958 - 12%	Hair 229 Blood 34	194 (85%) 34 (100%)	29 (13%)	5 (2%)	1
Norway House 2335 - 9%	Hair 218 Blood 30	214 (98%) 30 (100%)	3 (2%)	1	
South Indian Lake 655 - 13%	Hair 84 Blood 25	51 (61%) 25 (100%)	29 (35%)	4 (4%)	
Split Lake 1037 - 11%	Hair 116 Blood 0	99 (85%)	17 (15%)		
York Landing 425 - 9%	Hair 40 Blood 4	26 (65%) 4 (100%)	14 (35%)		
Total Pop. 8489 - 11%	Hair 898 Blood 93	788 (88%) 93 (100%)	99 (11%) -	10 (1%) -	1 -

CONVERSION:
20 ppb = 6 ppm
50 ppb = 15 ppm
(BLOOD) 100 ppb = 30 ppm (HAIR)

ppb - parts per billions (Blood)

ppm - parts per million (Hair)

CHAPTER 5. PROGRAM 4

5.1 Project 4.1, Public Awareness

As noted in the 1983/84 Annual Report the residents of the communities of South Indian Lake and Nelson House were selected as the main target audience for the public awareness program. A secondary target audience was also identified consisting of individuals and organizations with a special interest in mercury in the Agreement study area.

Public meetings were held in the communities of Nelson House and South Indian Lake on June 14, 1984 and June 15, 1984 respectively. Advertisement for these meetings consisted of radio announcements and posters. The radio announcements were made in English and in Cree, on CBC Radio North Country and the Native Communications Inc. broadcast, a couple of times a day, for approximately 10 days before each meeting. Posters announcing the meeting were sent to each community for display in public places, such as the nursing stations.

Efforts to attract as many people as possible to the meetings included making arrangements to have an English - Cree translator at each meeting. Mr. W. Thomas was the translator for the meeting in Nelson House. Unfortunately, arrangements to obtain a translator for the meeting in South Indian Lake were unsuccessful. Since each meeting was expected to last 3-4 hours, free refreshments were provided at each meeting. Attendance, at the meetings, however, was poor; approximately two dozen residents of Nelson House attended the meeting held there, while in South Indian Lake the meeting was attended by only 5 or 6 residents.

Three major topics were presented at each meeting. Dr. R. A. Bodaly gave a presentation on some of the basic parameters of mercury in the environment. This presentation focused on such concerns as what mercury is, that it is naturally found every where in the environment in small amounts, and that it can be changed into a form of mercury which can enter the aquatic food chain. It was also noted that certain conditions are particularly favourable to this transformation.

The next presentation topic was mercury levels in fish. It focused on such considerations as the levels of mercury that have been measured and the differences between species, lakes, and years sampled. This presentation was given by Mr. A. Derksen in Nelson House and by Dr. D. Bodaly in South Indian Lake.

The final presentation topic was mercury in people. The first part of this presentation was given by Ms. B. Young and it focused on the methods used to test mercury in people. The community health representative in each community kindly agreed to serve as the "guinea pig" for the demonstrations on how hair samples are obtained. The second part of this presentation was given by Ms. G. Marchessault and focused on what factors must be considered in obtaining a balance between the nutritional value of fish and its being a source of mercury in their diets.

Each of the public meetings began with a brief introduction by Ms. L. McKerness, the Canada-Manitoba Mercury Agreement Coordinator, concerning the purpose of the meeting. Numerous handouts were left at each meeting. Questions were encouraged throughout the presentations. The questions that were raised, particularly at the Nelson House meeting, were extremely helpful in determing the content of the videotape on mercury which was produced later in the year.

Partly because of the poor attendance at the public meetings and partly because of the fact that a videotape can be played for any number of people at any time of their choosing, it was decided to produce a videotape on mercury. The result was an approximately 10 minute long VHS videotape entitled "Mercury in the Churchill River Diversion".

This videotape was produced specifically for the residents of Nelson House and South Indian Lake. It was intended as an educational tool with a message of encouraging the residents of these communities to get tested for mercury. The English script for this videotape is reproduced as Appendix C in this report. The visual portion of the videotape consists primarily of existing colour slides obtained from various agencies. The total production cost for this videotape was approximately $3,500.

Copies of the English version of the tape were distriubted to the communities of South Indian Lake and Nelson House early in December, 1984. Copies have also been distributed to government and non government agencies interested in mercury in the Churchill River Diversion, such as Natural Resources, Environment Canada, the Northern Flood Committee and Manitoba Hydro.

The videotape has been well received with requests for copies greatly exceeding anticipated demand. For example, Health and Welfare Canada have been using the videotape as an educational and motivation tool in training the community health representatives in the mercury testing program being conducted on other reserves in Manitoba.

However, an important aspect of the videotape remains uncompleted. Because many of the residents of South Indian Lake and Nelson House speak only Cree, a Cree version of the videotape must also be produced. Efforts have been underway since the fall of 1984 to have the script translated and narrated into Cree. This process has been complicated by the fact that many of the words used to describe the basic concepts of mercury in the environment - such as the words "mercury" and "parts per million" - are not directly translatable into Cree.

Recently a new translator has been hired and as a result it is expected that a Cree version of the videotape will be available in late spring of 1985.

Another educational program initiated in 1984/85 involved the students of Grades 4 - 6 of Roland Lauze School in Nelson House. The purpose of this program was to increase the student's understanding of mercury and perhaps, their parents' as well through their discussions at home. A number of components were involved, with the central one being a teacher-led discussion. Background material was sent to the teachers for this purpose, including the answers to some commonly asked questions about mercury in the environment of Nelson House.

One particularly interesting aspect of the school program involves a "hands-on" project. Fish purchased from domestic fishermen will be brought to the school so that each child can measure and weigh his or her own fish. The fish are then to be wrapped individually and identified with the child's name, collected, shipped to Winnipeg, and analyzed for mercury. The results of the mercury analysis will then be discussed in class, such as the differences in mercury content of fish of different species and different size. As of March 31, 1985, this component of the school program had not yet been undertaken due to the repeated unsuccessful attempts to catch fish in the Nelson House area. It is hoped that with spring break-up, conditions will improve and the required number of fish will be caught.

Discussions have also taken place with Mr. A. Dysart, Principal of the Oscar Blackburn School in South Indian Lake, to introduce an educational program on mercury into his school. He was agreeable to the idea, but the full curriculum for the remainder of the 1984/85 school year prevented the incorporation of a new program this year. However, discussions will resume in late summer towards introducing this program into the 1985/86 curriculum for the Grades 4 - 6.

Other activities under Project 4.1 include a wide public distribution of the 1983/84 Annual Report and frequent contact with the Northern Flood Committee to keep them informed of the progress of the Agreement and of Project 4.1, in particular.

GLOSSARY

GLOSSARY

AEROBIC - living or active in the presence of free oxygen.

ANAEROBIC - living or active in the absence of free oxygen.

AUTOTROPHIC - applied to ORGANISMS which produce their own ORGANIC constituents from INORGANIC compounds, utilizing energy from sunlight or oxidation processes.

BENTHIC - pertaining to, or relating to BENTHOS.

BENTHOS - ORGANISMS that live on or in the bottom of bodies of water.

BIOACCUMULATION - the increasing concentration of a substance (e.g. MERCURY) up the food chain (e.g. from invertebrates, such as ZOOPLANKTON, to fish, to people).

BIOMASS - total quantity or weight of organisms in a given area.

BIVALENT - capable of combining with 2 atoms of hydrogen or their equivalent.

CARVIVORE - a flesh eating plant or animal.

CORRELATION - the study of the simultaneous variation of two or more variables. If one variable (e.g. mercury concentration) increases as the other increases (eg fish size) and decreases as the other decreases, there is said to be a positive correlation.

DEMETHYLATION - conversion of one type of chemical compound into another by the removal of the methyl group (CH_3-). The reverse of methylation.

ECOLOGY - a branch of science concerned with the interrelationship of ORGANISMS and their environment especially as manifested by natural cycles and rhythms, community development and structure, interaction between different kinds of ORGANISMS, geographic distribution, and population alterations.

ECOSYSTEM - an ecological community considered together with the nonliving factors of the environment as a unit.

FAUNA - the animal life of an area.

GANG NETS - a continuous length of GILL NET which consists of segments of different mesh sizes. The Department of Natural Resources uses a gang net consisting of panels of 1 1/2", 2", 3", 3 3/4", 4 1/4", and 5" of stretched mesh nylon. The Department of Fisheries and Oceans uses a gang net for their fish surveys consisting of panels of 3 1/2", 4 1/4", and 5 1/4" of stretched mesh nylon.

GILL NETS - a fishing net which entangles the fish by the gills.

HERBIVORE - a plant eating animal.

HETEROTROPHIC - applied to ORGANISMS which need ready made ORGANIC food material from which to obtain all their energy (e.g. HERBIVORES, CARNIVORES).

INORGANIC - not organic, not containing carbon or compounds of carbon (with a few exceptions).

ISOTOPE - one of a set of chemically identical types of atom which have the same atomic number but different mass numbers.

LIMNOCORRALS - enclosed experimental ECOSYSTEMS which are submerged and anchored in a body of water. The limnocorrals used in Project 2.1 were approximately 10 meters in diameter and 3-4 meters deep.

LIMNOLOGICAL PARAMETERS - various limnological characteristics such as oxygen concentration, pH, temperature, turbidity, species type and population, etc.

LIMNOLOGY - the scientific study of the physical, chemical, and biological conditions of fresh water, especially ponds and lakes.

MERCURY - a naturally occurring chemical element. It can exist in three different forms: as the pure element, a silver-white liquid used in thermometers; in an inorganic form, such as mercuric sulfide (HgS) found in bedrock; and in an organic form, such as methyl mercury (CH_3Hg-) found in fish.

METHYLATION - conversion of one type of chemical compound into another by the addition or incorporation of the methyl group (CH_3-) e.g. conversion of inorganic mercury to METHYL-MERCURY.

METHYL-MERCURY - an ORGANIC form of mercury, containing the methyl group (CH_3-), which has a high affinity for animal tissue and is concentrated up the food chain.

MICROBES - very minute OGANISMS.

MICROBIAL - pertaining to MICROBES.

NUTRIENT - any substance which promotes growth or provides energy for a living ORGANISM.

ORGANIC - relating to or derived from living ORGANISMS.

ORGANISM - a living being.

PEDOLOGICAL - pertaining to the science of natural soils.

pH - a measure of the acidity or alkalinity of a liquid. pH values can range from 0 (highly acidic) to 14 (highly alkaline) with a pH reading of 7 indicating a neutral solution.

PLANKTON - the passively floating or weakly swimming animal and plant life of a body of water consisting chiefly of minute plants and of minute animals that have only weak powers of movement.

p.p.m. - PARTS PER MILLION - one millionth of any measure (e.g. 1 minute in 2 years or 2 drops of oil in a 45 gal drum of gas).

RADIOACTIVE ISOTOPE - natural or artificial ISOTOPE exhibiting radioactivity. A radioactive isotope of mercury is used in Project 2.1 to provide a method for following the movement of mercury through the food chain.

SUBSTRATE - NUTRIENT medium for bacteria.

TROPHIC LEVEL - a stage in the food chain of an ECOSYSTEM. At the base of the food chain, the first trophic level, there are the producers. These are always green plants or other AUTOTROPHS which trap energy, almost always from light, and produce food substances, thereby making energy available for the other levels - the HERBIVORES AND CARNIVORES.

ZOOPLANKTON - animal life of the PLANKTON.

APPENDIX A

1984/85 AGREEMENT PARTICIPANTS

CANADA-MANITOBA AGREEMENT ON THE STUDY AND MONITORING OF MERCURY IN THE CHURCHILL RIVER DIVERSION

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APPENDIX B

"WORK-IN-PROGRESS" MEETING

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R. Webster	Health and Welfare Canada (Winnipeg)
C. Abbott - Hommel	Health and Welfare Canada (Thompson)
T. Bonish	Health and Welfare Canada (Thompson)
T. Keeshaw	Health and Welfare Canada (Thunder Bay (Part)
E. Ongley	Environment Canada
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W. Warwick	Environment Canada
R. Woychuk (for V. Chacko)	Environment Canada
D. Kimmett	Environment Canada
S. Fenety	Environment Canada
D. Bodaly	Fisheries and Oceans
R. E. Hecky	Fisheries and Oceans
S. Law	Fisheries and Oceans
G. McGregor	Fisheries and Oceans
R. Josephson	Fisheries and Oceans
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D. Brown	Environment and Workplace Safety and Health
A. Beck	Environment and Workplace Safety and Health
E. Kucera	Environment and Workplace Safety and Health
D. Williamson	Environment and Workplace Safety and Health
J. O'Connor	Natural Resources
A. Derksen	Natural Resources
M. Shoesmith	Natural Resources (Part)
P. Warner	Health
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B. Rannie	Agassiz Systems Research and Technology
E. Punter	Agassiz Systems Research and Technology
J. Guthrie	Agassiz Systems Research and Technology
L. McKerness	Canada-Manitoba Mercury Agreement

APPENDIX C

SCRIPT OF VIDEOTAPE "MERCURY IN THE CHURCHILL RIVER DIVERSION"

NARRATOR: THE LAKES AND THE LAND HAVE NOT ALWAYS BEEN AS WE SEE THEM NOW.

SOMETIMES NATURE CHANGES THEM...

SOMETIMES MAN CHANGES THEM.

IN 1977 and 1978 THE COMMERCIAL FISH CAUGHT ALONG THE CHURCHILL RIVER DIVERSION SHOWED ELEVATED LEVELS OF MERCURY... IN SOME CASES THESE LEVELS WERE HIGHER THAN 0.5 PPM WHICH IS THE CANADIAN GUIDELINE FOR MERCURY IN COMMERCIAL FISH.

ALTHOUGH MERCURY HAS ALWAYS BEEN IN THE ENVIRONMENT... IT IS FOUND IN ROCKS, SOIL, WATER, AIR, PLANTS, AND ANIMALS... THE SUDDEN INCREASE FOUND IN THE FISH WAS CAUSE FOR CONCERN.

ALMOST ALL THE MERCURY FOUND IN ROCK, SOIL, AND LAKE BOTTOM IS IN ITS INORGANIC FORM.
BUT IT CAN CHANGE TO AN ORGANIC FORM CALLED METHYL-MERCURY.
METHYL-MERCURY CAN BE HARMFUL TO ALL ANIMALS AND PEOPLE.

IN LAKE BOTTOM SEDIMENTS AND IN WATER THE CHANGE TO METHYL-MERCURY OCCURS NATURALLY, BUT VERY SLOWLY. HOWEVER WHEN SOIL AND VEGETATION ARE FLOODED, IT CAN HELP TO MAKE THIS CHANGE OCCUR MUCH FASTER. THIS IS WHAT HAPPENED THROUGHOUT A LARGE PART OF THE CHURCHILL RIVER DIVERSION AREA...

ONCE THE METHYL-MERCURY IS IN THE LAKE SEDIMENTS OR WATER, IT CAN BE TAKEN UP BY SNAILS, CLAMS, AND INSECT LARVAE.

METHYL-MERCURY COMBINES WITH ANIMAL TISSUE AND IS CONCENTRATED UP THE FOOD CHAIN.
IN OTHER WORDS, THE LEVELS OF MERCURY INCREASE AS SMALLER FISH, THAT HAVE EATEN SNAILS AND INSECT LARVAE, ARE EATEN BY LARGER FISH.

YOU CANNOT SEE THE MERCURY IN FISH. IT DOES NOT MAKE THE FISH SMELL BAD, CHANGE ITS COLOUR OR SHAPE, NOR HAVE THE LEVELS BEEN HIGH ENOUGH TO KILL THE FISH.
BUT IT IS THERE. IT HAS BECOME PART OF THE FISH MUSCLE AND LIVER.

IN THE NELSON HOUSE AREA ONLY ONE LAKE...WUSKWATIM LAKE...
HAD FISH ANALYZED BEFORE THE FLOODING OCCURRED. FROM 1970 to 1977 THE WALLEYE FROM WUSKWATIM LAKE HAD MERCURY LEVELS OF 0.25 TO 0.44 PARTS PER MILLION. AFTER THE FLOODING, THE MERCURY LEVELS ROSE... TO 0.76 PARTS PER MILLION IN 1979 AND TO ONE PART PER MILLION IN 1980.

IN SOUTHERN INDIAN LAKE A NUMBER OF FISH SPECIES, FROM DIFFERENT PARTS OF THE LAKE, WERE ANALYZED BOTH BEFORE AND AFTER THE FLOODING. HERE TOO THE MERCURY LEVELS ROSE AFTER FLOODING.

ALTHOUGH THE MERCURY LEVELS IN THE FISH FROM SOUTHERN INDIAN LAKE HAVE NOT BEEN AS HIGH AS IN FISH FROM THE LAKES NEAR NELSON HOUSE, ONLY THE MERCURY LEVELS OF THE WHITEFISH FROM SOUTHERN INDIAN LAKE HAVE STARTED, SINCE 1978, TO RETURN TOWARDS NORMAL.

IN FISH, SUCH AS PIKE AND WALLEYE, THAT ARE HIGHER UP THE FOOD CHAIN, THE HIGHER LEVELS OF MERCURY WILL PROBABLY REMAIN FOR A FAIRLY LONG TIME.

MERCURY LEVELS IN FISH ARE HIGHEST IN THE RAT AND NOTIGI LAKES, WHICH WERE WIDELY FLOODED. THE LEVELS ARE LOWER IN FOOTPRINT, THREEPOINT AND WUSKWATIM LAKES, AND LOWEST IN SOUTHERN INDIAN LAKE WHICH HAD THE LEAST AMOUNT OF FLOODING.

IN CANADA, INCREASED MERCURY LEVELS IN FISH HAVE BEEN FOUND AFTER FLOODING HAS OCCURRED IN OTHER RESERVOIRS LOCATED IN NORTHERN QUEBEC, LABRADOR, NORTHERN BRITISH COLUMBIA, AND SOUTHERN SASKATCHEWAN. UNFORTUNATELY IT IS ONLY SINCE THE LATE 1970'S THAT THIS PROBLEM HAS BECOME KNOWN.

EVEN IN FLOODED LAKES, WHERE MERCURY LEVELS IN THE FISH ARE QUITE HIGH, THE LEVELS OF MERCURY IN THE WATER ARE SO LOW THAT IT IS UNDETECTABLE. THEREFORE THE WATER IS SAFE TO DRINK.

BECAUSE MERCURY IS CONCENTRATED UP THE FOOD CHAIN, MINK TAKEN ALONG THE BURNTWOOD RIVER ARE BEING ANALYZED FOR THEIR MERCURY CONTENT.
IN 1980 MINK SAMPLES SHOWED MERCURY LEVELS THAT WERE TEN TIMES HIGHER THAN THOSE IN THE FISH FROM THE SAME AREA.
THE AVERAGE LEVELS OF MERCURY IN THE MINK SAMPLED WERE MUCH HIGHER THAN LEVELS FOUND IN MINK FROM OTHER PARTS OF MANITOBA WHERE MERCURY IS NOT A PROBLEM.

MICE ARE ALSO BEING SAMPLED TO SEE IF THE MERCURY LEVELS IN ANIMALS THAT LIVE AND FEED ON LAND ARE ALSO BEING AFFECTED.

MERCURY LEVELS IN PEOPLE CAN INCREASE FROM EATING FISH THAT CONTAIN MERCURY.

THE AMOUNT AND THE TYPE OF FISH YOU EAT WILL INFLUENCE THE MERCURY LEVELS IN YOUR BODY.

THERE IS ONLY ONE WAY TO TELL WHAT THE MERCURY LEVELS OF THE FISH ARE... THEY MUST BE TESTED IN A LAB.
THERE ARE TWO WAYS IN WHICH TO DETERMINE WHAT THE MERCURY LEVEL IS IN YOUR BODY...
EITHER A HAIR OR A BLOOD SAMPLE MUST BE TAKEN FOR ANALYSIS.

IT IS IMPORTANT THAT YOU KNOW YOUR MERCURY LEVEL. IF YOUR TEST SHOWS THAT MERCURY IS HIGHER THAN NORMAL, YOU MAY DECIDE TO EAT LESS FISH, OR FISH WITH LOWER MERCURY LEVELS SUCH AS WHITEFISH, UNTIL YOUR LEVEL IS BACK TO NORMAL.

IF YOU ARE A WOMAN AND IF YOU ARE PREGNANT, IT IS ESPECIALLY IMPORTANT TO YOUR BABY THAT YOUR MERCURY LEVEL BE WITHIN THE NORMAL RANGE.

HOW DO YOU DECIDE WHETHER OR NOT TO CHANGE THE AMOUNT OR THE KIND OF FISH YOU EAT?
HOW MUCH OF A CHANGE SHOULD YOU MAKE.
A LOT, A LITTLE, OR NO CHANGE AT ALL?
FIRST, HAVE YOURSELF TESTED FOR MERCURY.
AT THE NURSING STATION YOU WILL BE SHOWN HOW QUICK AND PAINLESS IT IS TO HAVE YOUR HAIR SAMPLED FOR MERCURY.

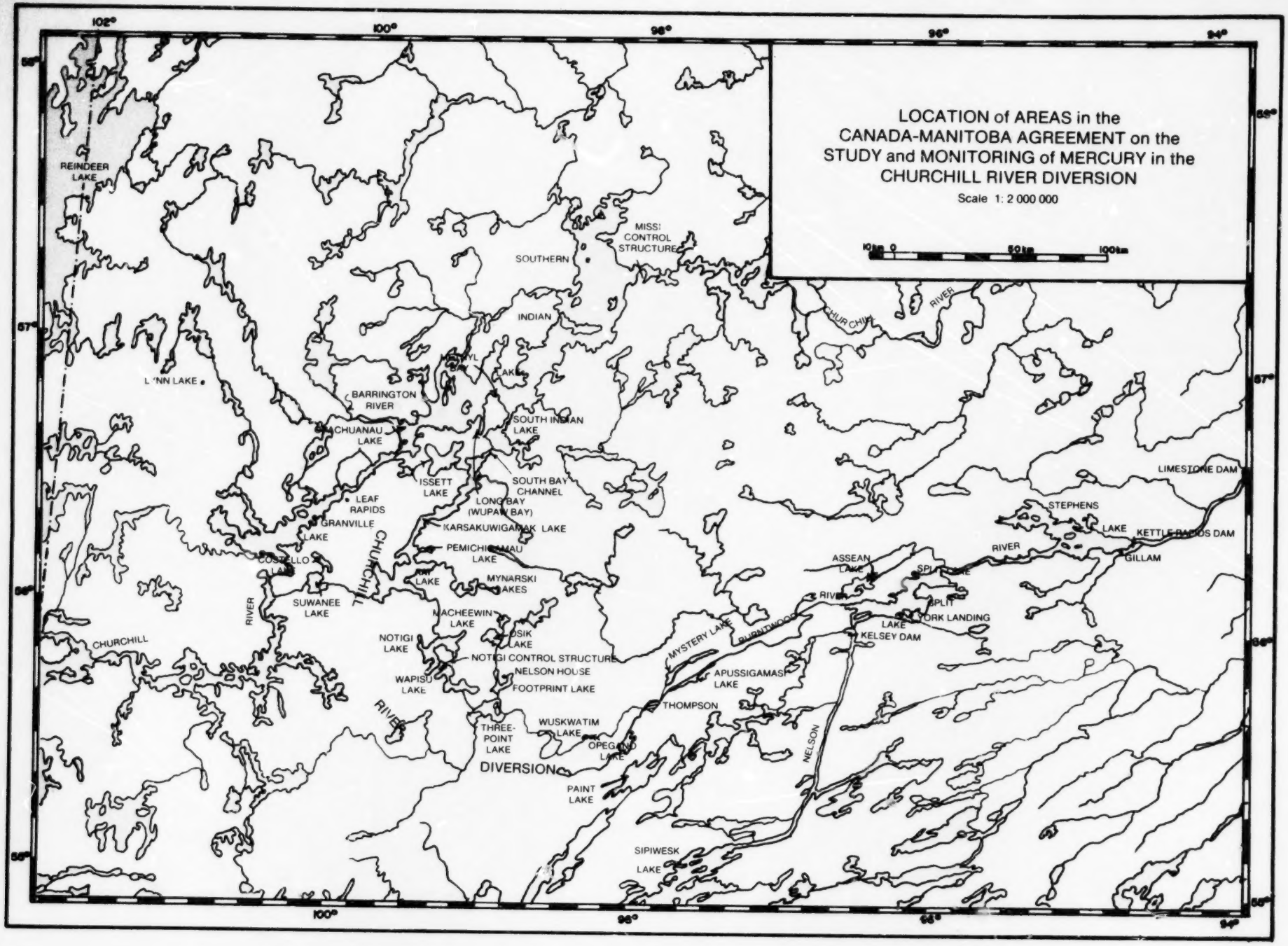
THE RESULTS OF YOUR TEST WILL BE RETURNED IN ABOUT SIX WEEKS... TWO TO THREE WEEKS IF YOU ARE PREGNANT. IF YOUR LEVEL IS IN THE NORMAL RANGE YOU WILL NOT NEED TO CHANGE YOUR FISH EATING HABITS.
ADVICE WILL BE PROVIDED TO YOU ON HOW TO LOWER YOUR MERCURY LEVEL IF IT IS HIGHER THAN NORMAL.

INFORMATION ON THE SYMPTOMS OF MERCURY POISONING IS ALSO AVAILABLE AT THE NURSING STATION.
YOU AND YOUR FAMILY'S HEALTH IS IMPORTANT. PLEASE, GET TESTED.

APPENDIX D

LOCATION MAPS

Province of Manitoba
Surveys and Mapping Branch
MANITOBA
Scale 1 : 5 000 000
Kilometres 20 0 100 Kilometres
Cartography by: Surveys and Mapping Branch, Manitoba 1980
© Province of Manitoba 1980
Churchill
Nejanilini Lake
Seal River
Tadoule Lake
Brochet
Reindeer Lake
Big Sand Lake
Southern Indian Lake
Lynn Lake
Churchill River
Leaf Rapids
Stephens Lake
Gillam
Split Lake
Split Lake
York Landing
Nelson River
Hayes River
Gods River
Highrock Lake
Nelson House
Thompson
Sherridon
Sipiwesk Lake
Knee Lake
Flin Flon
Wekusko Lake
Wabowden
Cross Lake
Gods Lake
Cormorant Lake
Little Playgreen Lake
The Pas
Norway House
Island Lake
Berens River
Swan River
Gypsumville
Winnipegosis
Dauphin
Hodgson
Bissett
Russell
McCreary
Lake Manitoba
Gimli
Pine Falls
Shoal Lake
Neepawa
Selkirk
Portage la Prairie
Brandon
Virden
Assiniboine River
Winnipeg
Steinbach
Glenboro
Red River
Morris
Killarney
Deloraine
Morden
Emerson
Sprague


LOCATION of AREAS in the
CANADA-MANITOBA AGREEMENT on the
STUDY and MONITORING of MERCURY in the
CHURCHILL RIVER DIVERSION
Scale 1: 2 000 000
0
50 km
100 km
102°
100°
98°
96°
94°
58°
57°
56°
REINDEER LAKE
L'NN LAKE
SOUTHERN
INDIAN
MISSI CONTROL STRUCTURE
BARRINGTON RIVER
CHUANAU LAKE
SOUTH INDIAN LAKE
ISSETT LAKE
SOUTH BAY CHANNEL
LONG BAY (WUPAW BAY)
LEAF RAPIDS
GRANVILLE LAKE
KARSAKUWIGAMAK LAKE
PEMICHIGAMAU LAKE
COSTELLO LAKE
MYNARSKI LAKES
SUWANEE LAKE
CHURCHILL RIVER
MACHEEWIN LAKE
NOTIGI LAKE
OSIK LAKE
NOTIGI CONTROL STRUCTURE
NELSON HOUSE
WAPISU LAKE
FOOTPRINT LAKE
THREE-POINT LAKE
WUSKWATIM LAKE
OPEGANO LAKE
DIVERSION
PAINT LAKE
SIPIWESK LAKE
THOMPSON
APUSSIGAMASH LAKE
MYSTERY LAKE
BURNTWOOD
NELSON RIVER
KELSEY DAM
SPLIT LAKE
YORK LANDING
ASSEAN LAKE
GILLAM
STEPHENS LAKE
KETTLE RAPIDS DAM
LIMESTONE DAM